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thickness of the spacer layer, at very little cost but provides very accurate impedance control.

[0115] FIG. 4 illustrates:

[0116] The stacking of multiple layers of air-dielectric assembly.

[0117] The use of a single metal plate between dielectric layers.

[0118] And can be applied to any other combination such as differential pairs and data busses.

[0119] FIG. 5 illustrates an offset method of construction for a multi-layer assembly:

[0120] For improved signal trace density

[0121] With cost effective forming or stamping possible with sheet metals.

[0122] FIG. 5A

[0123] illustrates a offset construction method

[0124] combined with differential traces.

DETAILED DESCRIPTION OF THE INVENTION

[0086] Air used as a dielectric has the lowest dissipation factor and the lowest dielectric constant of all dielectric materials. Since the dissipation factor is nearly zero, the high frequency losses in the dielectric are nearly eliminated, and for high frequency signals, the dominant remaining losses are skin effect and radiation losses. Since the dielectric constant of air is essentially one (1) the velocity of propagation is nearly the speed of light.

[0087] In contrast standard PCB materials have dielectric losses which are the dominant loss factor above 1 or 2 Ghz. The skin effect and radiation are the same as in air but being a smaller percentage of the total loss. Also, typical PCB materials have a dielectric factor

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ranging from 2 to 4, which results in the propagation through the board being reduced to $1/\sqrt{\text{dielectric factor}}$ or from 0.7 or 0.5 which alternatively stated, the delay is increased by 50 percent to about 100 percent of the velocity in air.

[0088] Both the dielectric constant and the dielectric loss factor are frequency dependent which causes dispersion of the transition from one voltage state to another. The result is deformed and extended rise-time and fall-time, and jitter in the eye pattern. This results in data errors and poor bit-error-rates.

[0089] In order to use air as the primary dielectric in a PCB, a structure resembling suspended substrate is used. A metal trace is suspended in air on a thin dielectric much like a road on a bridge across a large air space is suspended. The bridge being the thin dielectric, the road being the trace, and the air being the air above and below.

[0090] In the PCB, two conductive planes, one above and one below provide the signal return, reference and shielding. These two planes may be power or ground planes but are not required to be power or ground.

[0091] The air dielectric is typically formed by adding spacing layers above and below the thin dielectric layer supporting the signal trace. Conductive planes above and below the spacers provide the AC ground return for the signal on the signal trace. The spacing material may be either conductive, resistive, or insulated, and need not be uniform in composition. The spacing may also be made by milling or otherwise forming an indentation to insulate the conductive planes from the traces, by any process including, but not limited to etching, plating, milling, punching, drawing, forming, or stamping

[0092] The dielectric layer(s) is(are) laminated with the formed metal planes, or the metal planes with the metal spacer layer.

Connection of the conductive traces to vias:

[0093] A simple method for making interconnect (vias) is to drill oversized holes in the metal planes or spacers before lamination, add

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dielectric to fill the oversized holes, and form the air channels, usually by etching. After lamination, via holes are drilled and plated as in standard PCB processing.

Improved Performance or Operation

[0095] The PCB will have much better impedance control compared to standard PCB tolerances for two reasons. First, the depth tolerance of can be much better controlled than the tolerance of standard dielectric material which flows and is non-uniform compared with sheet metal spacer that sets the spacing. Secondly, the dielectric constant of air one and does not vary, compared with standard materials which vary across a broad range.

[0096] The use of air dielectric provides a very low dielectric loss factor for high frequency, microwave and high speed digital signals up into the gigahertz and gigabit frequencies, compared to standard dielectric materials.

[0097] The use of air dielectric provides the shortest time delay or the fastest transition time for a given trace length, compared to standard dielectric materials. Epoxy fiberglass material has a delay of approximately 2.times. the free space velocity of light while this application of air dielectric can approach the free space velocity of light.

[0098] Air dielectric also minimizes the dispersion of the transition of the signal from one voltage to another caused by frequency dependent dielectric losses and phase shift which are not present in air.

[0099] The use of air dielectric increases the trace impedance for traces with the same width to height ratio by a factor of approximately 2. Alternatively stated, for a given impedance and trace width, the height may be reduced by a factor of approximately 2.

[0100] Where a data-bus or non-synchronous signals share the same channel, the cross-talk from signal to signal within the same channel can be reduced by the use of an air dielectric and by reducing the height spacing of the trace to the metal plate compared to the cross-

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talk of a strip-line transmission line with the same impedance and the same spacing of traces.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0104] The most likely embodiment at the present time is the configuration of FIG. 2 with the top conductive layer and bottom conductive layer being a sheet of 1 mill copper. The two spacer layers would be photo-etched metal approximately 4 mils thick available from several vendors. The signal trace will be approximately 6 mils wide on a dielectric layer of FR4 approximately 1 mil thick. The channel will be approximately 10 mils wide. The impedance will be approximately 50 ohms and will have a transit time approximately 90% of the speed of light, and an RF attenuation attributable only to skin effect and DC loss.

[0105] Via preparation will use oversize drilling of the metal sheets, filling these drill holes with dielectric material by squeegee or by pressing, and curing the dielectric. At this point standard PCB fabrication and assembly will begin complete the process.

[0125] The present invention of embedding an air dielectric in a PCB is targeted at analog and digital markets with highly improved performance at minimum cost differential compared to standard PCB manufacture. In fact, the material cost will be lower than required using standard materials and techniques.

[0126] The impedance of all the applications and figures used in this invention is especially uniform through the structure, both from layer to layer, and from trace to trace on the same layer because we do not deal with a dielectric material which varies in thickness, in dielectric constant and loss factor from piece to piece, from batch to batch, from location to location on the same laminate, but only with the thickness of metal sheet or foil which is rolled to very tight tolerances.

[0127] The manufacture of standard PCBs with impedance controlled within 10% typically adds 20 percent to the cost of the boards and tolerances tighter than 7% are not obtainable except at huge cost premiums. The reason for this cost premium is that the partially laminated board must be tested for impedance, the etching time and

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material selection adjusted to make up for material variations and finally assembled. No process adjustment can make up for variations in thickness and material across the board.

[0128] This invention will make possible the manufacture of boards with impedances controlled under 5 percent standard, and 2 percent economically practical when needed.

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